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Improvement in performance and emissionsparameters of a single cylinder common rail direct injection compression ignitionengine

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Abstract : This experimental work focuses on the analysis of the performance and emission parameters related to the injection pressure, injection timing and injector location in a modified single cylinder naturally aspirated water cooled common rail diesel engine with a compression ratio of 16:1.The main objective of this experimental work was to evaluate the best injection pressure of diesel that was injected into the cylinder and optimum injector location with respect to the cylinder axis. It was evident from the experimental data that the injection pressure of 50MPa was found to be best in terms of brake thermal efficiency obtained for entire operating range of brake mean effective pressures. The optimum injector location was also identified at full load operation with its corresponding best injection timing at which the maximum torque was obtained. It was seen that the level of smoke emission in common rail direct injection system significantly reduced as compared to conventional mechanical injection system. High level of nitric oxide was noticed in a common rail direct injection system due to advanced injection timing of diesel that was essential to achieve maximum possible thermal efficiency.
Keywords : Common rail direct injection (CRDI) system, injection pressure, injection timing, injector location and engine emissions.

1. Introduction

The compression ignition (CI) engines have been widely used as a prime movers in transportation sector throughout the world due to its fuel economy, durability and robustness. This kind of combustion mode emits extremely low level of hydrocarbon (HC) and carbon monoxide (CO) emissions as compared to conventional spark ignition (SI) engines because of less wall wetting and also the fuel is being injected into the cylinder where the pressures and temperatures are quite high which enhances the air-fuel mixture formation. However, the high level of oxides of nitrogen (NO_X) and particulate matter (PM) emissions are the major issues associated with CI mode of combustion.Meanwhile, the use of after treatment devices such as exhaust gas recirculation (EGR), selective catalytic reduction (SCR), variable geometry turbocharger (VGT), variable valve timing (VVT), variable compression ratio (VCR) and catalytic converters can minimize the emissions level considerably to meet the stringent emissions norms.On other hand, the level of engine emissions and fuel consumption could be reduced through the utilization of a modern common rail direct injection (CRDI) system with implementation of sophisticated electronic controller for altering the injection parameters such as injection timing, injection pressure, number of injection pulses per cycle and injection duration to achieve optimum performance and emissions characteristics[1,2].However, the performance of CI engines is stronglydepends on the injection parameters. In fact, the precise control over the fuel injection parameters could be obtained using a modern CRDI system equipped with electronic control unit (ECU) to alters the controlling parameters. The quantity of diesel and injection timing could significantly alters the parameters related to performance, emissions and combustion. The diesel fuel injection system delivers fuel at relatively higher injection pressures as compared to the conventional SI engines due to poor volatility of diesel. This implies that the system component designs and materials should be chosen in order to withstand highermechanical stresses and also precision and tighttolerances are required for the system to work efficiently[1, 2, 3]. The influence of injection pressure and injection timing on particulate size number and spray characteristics has been analyzed in a single cylinder modern common rail direct injection diesel engine fuelled with biodiesel. It was evident from the experimental results that higher injection pressure leads to longer spray tip penetration and larger spray area thanthat of low injection pressure.With retarded injection timing, the size of the particulate increased significantly as compared to the advanced injection timing.Enrichment a little quantity of biodiesel helps in reducing the size of particulate emissions[4]. The characteristics of spray and atomization process has been studied using high speed schelerin method. The parameters such as spray tip penetration, spray cone angle, projected spray area and sprayvolume were measured. They have also investigated the characteristics of droplet size, number density and droplet sauter mean diameter (SMD) at certain location[5].The new kind of injector was developed by which operates at injection pressure of 250 MPa in a modern common rail diesel engine[6]. This injector helps in reducing the return fuel at optimum injection pressure of 200 MPa. It has been noticed that higher injection pressure leads to relatively smaller fuel droplet as compared to the lower injection pressure irrespective of the types of fuels used[7]. The angle of fuel spray cone converges significantly with increase in injection pressure[7, 8]. The objective of the present work was to evaluatethe effects of injection pressure and injector location with respect to cylinder axis on a single cylinder diesel engine with mechanical injection system which was modified to operate on a high pressure common rail injection system.In this study, experiments were performed at various brake mean effective pressures (BMEPs) at best injection pressure and comparison were made between conventional diesel baseline (mechanical injection system) and CRDI system.

2. Engine setup and measuring instruments used for this experimental work

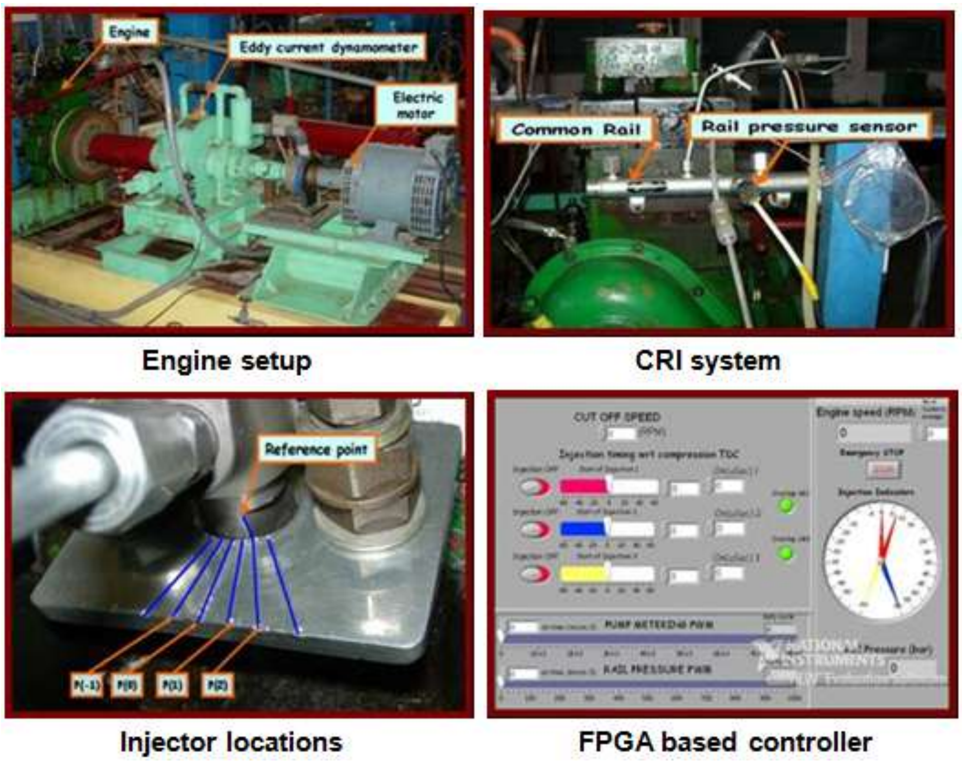

Fig.1 Photographic view of the experimental setup used

Figure 1 depicts the photographic view of the experimental setup used in this work. The engine specifications are listed in Table 1. The schematic diagram of the experimental setup is shown in Fig.2. A common rail direct injection (CRDI) system was used for fuel injection. The control software for the system was developed as a part of this work. The control logic and framework for control and also the driver circuits were developed. The software was developed as a part of this work. The field programmable gate array (FPGA) based system can vary the injection timing, injection duration and number of injection pulses. The injector was fed with a peak and hold pulse and the peak duration could be varied. It was set at 220 µs. Fuel flow was measured on the mass basis using weighing machine with a resolution of 0.01g. Air Flow was measured using a positive displacement flow meter with a surge tank connected on the suction side. Smoke emission was measured using AVL (415 S) variable sampling smoke meter and nitric oxide (NO) emissions was measured using chemiluminescence NO_X analyzer.

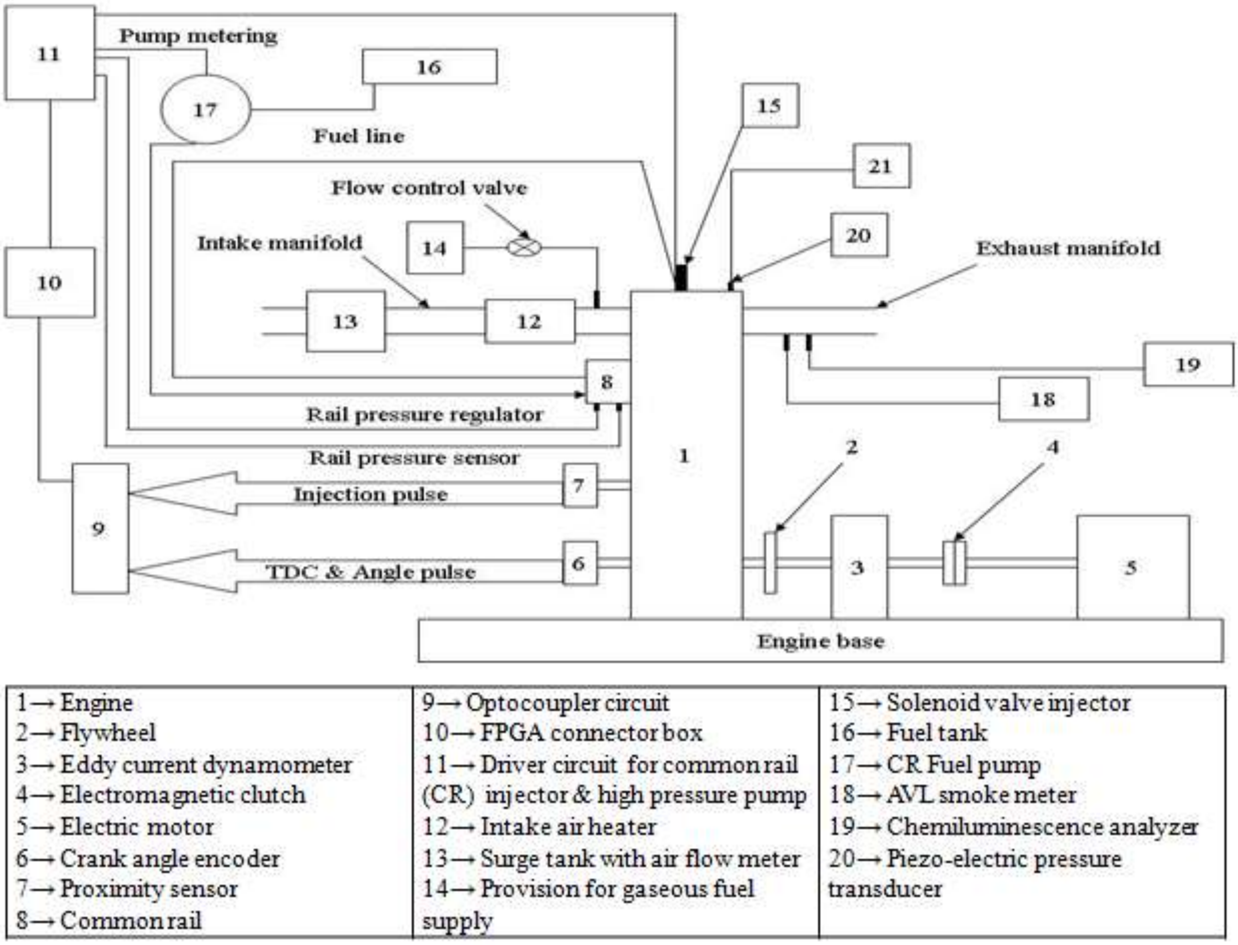

Fig.2 Schematic diagram of the experimental setup used for a CRDI system

Table 1. Engine specifications

Engine type	Single cylinder. 4-Stroke, naturally aspirated, water cooled, direct injection CI engine
Bore X Stroke	80 mm X 110 mm
Connecting rod length	231 mm
Compression ratio	16
Rated power	3.7 kW@1500 rpm
Injection system	Modified to high pressure common rail injection (CRI) system

3. Experimental procedure

Experiments were first conducted with the conventional injection system at various brake mean effective pressures at the optimum injection timing in the diesel mode.Using the developed common rail injection (CRI) system, experiments were conducted by varying the injection pressure of diesel ranging from 40 MPa to 100 MPa. The best injection timing (maximum torque condition) for various BMEP was maintained at the injector position P(0). The optimum injection pressure was determined. The common rail solenoid injector was rotated and kept at different positions say P(0), P(1), P(2) and P(-1) are shown in Fig.1. At each position, thermal efficiency, smoke and nitric oxide (NO) levels were measured at full load and compared to fix the best location. At the best injector location and injection pressure, experiments were performed at different operating BMEPs ranging from 1 bar to 5.39 bar. The results obtained at the best injection timing were compared with the base engine data.

4. Results and discussion

4.1 Effect of injection pressure on brake thermal efficiency at various BMEPs

Figure 3 indicates the effect of injection pressure at various operating BMEPs. In all cases the injection timing that gives the highest torque was used. We see that the injection pressure of 50 MPa is the best at all operating outputs. It has been reported that higher injection pressures could lead to wall impingement of the fuel due to higher spray velocities. In this study, the injection pressure was varied from 40 MPa to 100 MPa in steps of 10 MPa. However, the results of optimum injection pressure was plotted against brake thermal efficiency. It was identified through experiment that 50 MPa found to be the best injection pressure based on highest possible brake thermal efficiency.It may be noted that this experiment was conducted at injector position P(1) as depicted in Fig.1.

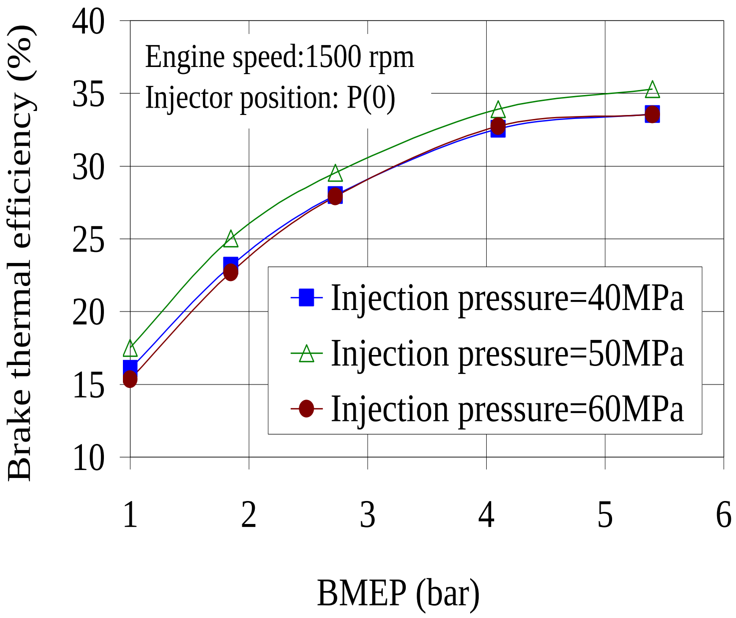

Fig.3 Effect of injection pressure on brake thermal efficiency

4.2 Effect of injector locations on performance and emissions parameters at full load conditions with optimum injection pressure

The effect of injector position at the best injection timing and full load is seen in Fig.4. We see that the injector position 1 is the best from the point of view of brake thermal efficiency and smoke emission. Experiments were performed in CI mode at various locations of the injector with respect to the cylinder axis. Thereby, the optimum position of the injector could be obtained in order to achieve improved thermal efficiency with low level of emissions.However, good combustion leads to high level of nitric oxide (NO) emission of about 200 ppm, which led to better thermal efficiency as compared to the other positions of the injector namely P(-1), P(0) and P(2) respectively.

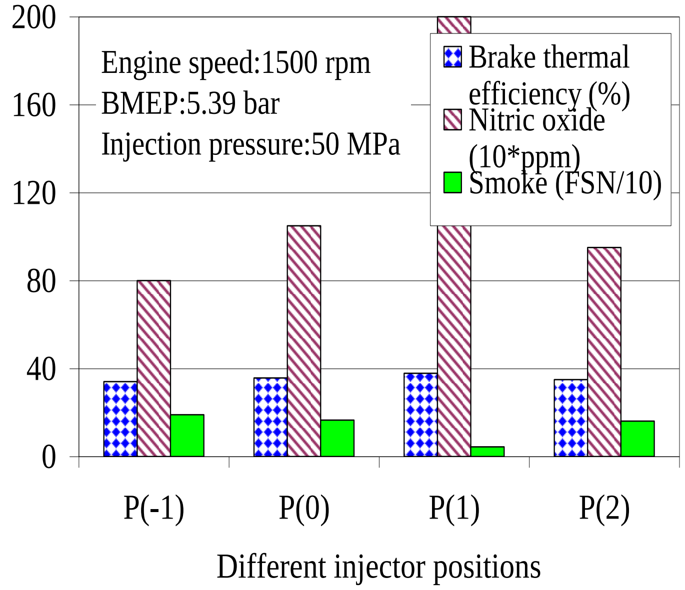

Fig.4 Effect of injector position on performance and emissions characteristics

4.3 Comparison of a CRDI systemwith conventional mechanical diesel injection system

Subsequently experiments were also conducted at different BMEPs at the best injection pressure and injector position. We see that the brake thermal efficiency is significantly higher with the common rail system as shown in Fig.5. This is due to good atomization of the fuel and proper control of the injection timing.

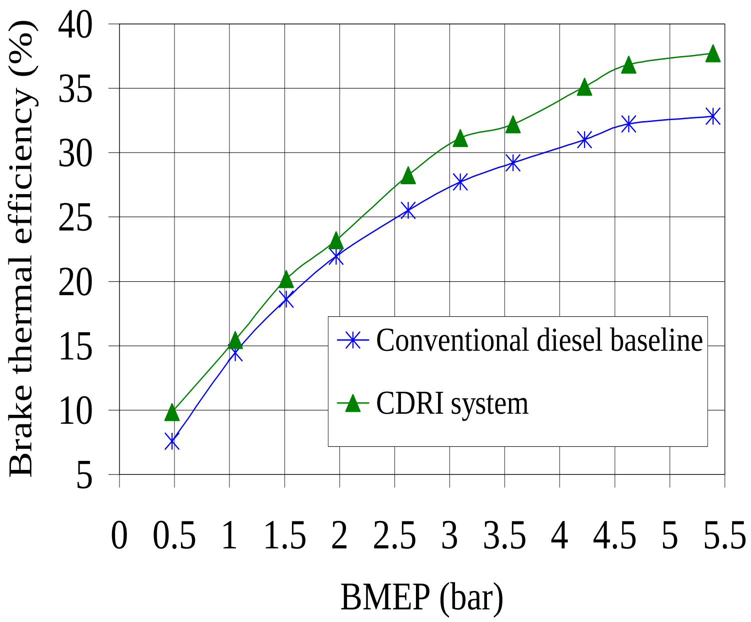

Fig.5 Variation of brake thermal efficiency with BMEP

Smoke emission as seen in Fig.6 is also extremely low due to good mixture preparation. Figure 7 indicates the level of nitric oxide (NO) emissions.It was observed that good combustion on account of finely atomized fuel spray and advanced injection timing of diesel leads to high level of NO emissions.

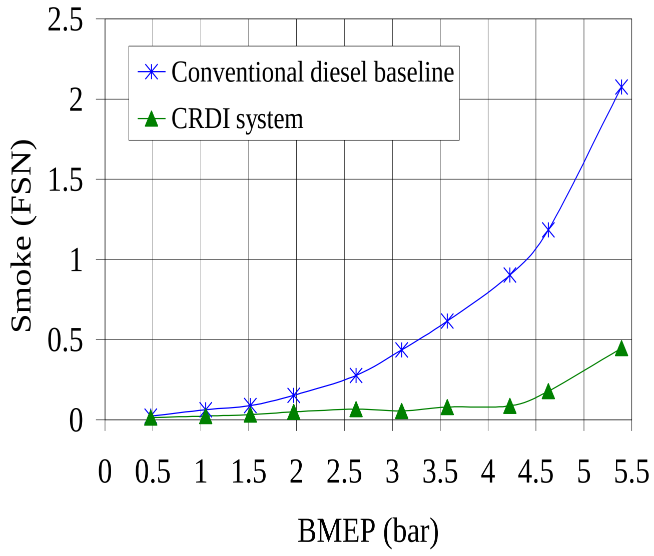

Fig.6 Variation of smoke with BMEP

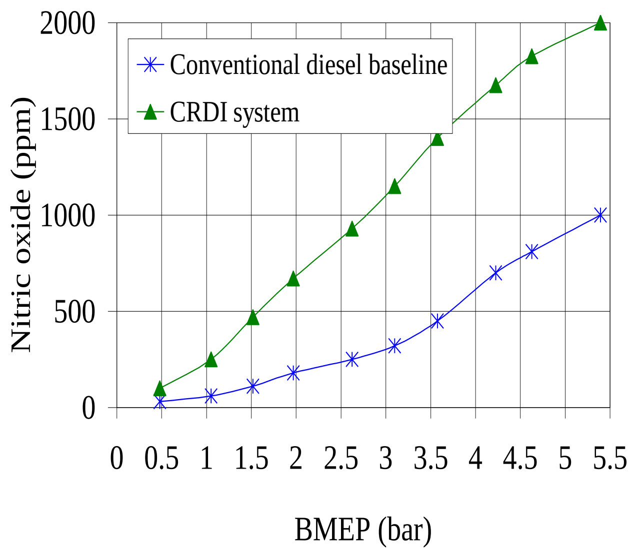

Fig.7 Variation of nitric oxide withBMEP

The best injection timings as seen in Table 2 are quite advanced. The static injection timing for the base engine is 23°BTDC. The dynamic injection timing will at least be about 8 to 10°CA retarded than this for the conventional diesel engine.

Table 2. Best injection timings at various operating BMEPs

BMEP (bar)	**Injection timing (°BTDC)**
1.05	18
1.97	20
3.09	22
4.23	23
4.62	23
5.39	23

This is the reason for the high NO levels. Retarding the injection timing will lower NO levels, however at the expense of smoke emissions. This will be tried later. Improved combustion leads to lower exhaust gas temperatures as seen in Fig.8. Higher thermal efficiency means lesser amount of fuel injection and this lowers the exhaust gas temperature.

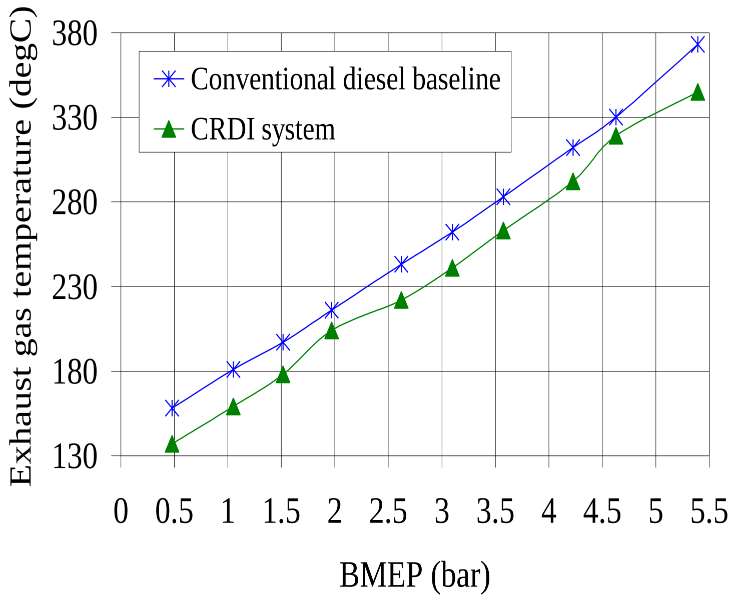

Fig.8 Variation of exhaust gas temperature with BMEP

5. Conclusions

Based on the experimental analysis of a modern common rail diesel engine, the essential conclusions were made as follows:

- The injection pressure of 50 MPawas found to be optimum in terms of brake thermal efficiency and engine emissions.
- The best injector location with respect to the cylinder axis was determined as P(1) which gives relatively higher thermal efficiency as compared to the other position of the injector such as P(-1), P(0) and P(2) respectively.
- As seen in the results, the brake thermal efficiency obtained in CRDI system is higher than that of conventional mechanical injection system.
- NO level is considerably high for CRDI system because of advanced injection timing of diesel as needed to obtain best thermal efficiency.

On the whole, the CRDI system enables efficient combustion and also has potential to perform better in terms of performance and emissions with proper selection of injection pressure, injection timing and injector location with respect to the cylinder axis of an engine.

References

1. Heywood J.B., Internal combustion engine fundamentals. McGraw-Hill, Inc., 1988.
2. Ganesan V. Internal combustion engines. Tata McGraw-Hill, Second edition, 2006.
3. L. Karikalan and M.Chandrasekaran. Effect of varying fuel injection pressure of Selective Vegetable oil biodiesel on C.I engine performance and pollutants. International Journal of ChemTech Research, Vol.8, No.12, 2015; 312-318.
4. Avinash Kumar Agarwal, AtulDhar, Jai Gopal Gupta, Woong Il Kim, Chang Sik Lee, Sungwook Park. Effect of fuel injection pressure and injection timing on spray characteristics and particulate size–number distribution in a biodiesel fuelled common rail direct injection diesel engine. Applied Energy 2014; 130 : 212–221.

5. Jun Mo, Chenglong Tang, Junge Li, Li Guan, Zuohua Huang. Experimental investigation on the effect of n-butanol blending on spray characteristics of soybean biodiesel in a common-rail fuel injection system. Fuel 2016; 182:391–401.
6. LianDuan, Shou-qi Yuan, Lin-feng Hu, Wen-ming Yang, Jian-da Yu, Xing-lan Xia..Injection performance and cavitation analysis of an advanced 250 MPa common rail diesel injector. International Journal of Heat and Mass Transfer 2016; 93:388–397.
7. Pin-Chia Chen, Wei-Cheng Wang, William L. Roberts, Tiegang Fang. Spray and atomization of diesel fuel and its alternatives from a single-hole injector using a common rail fuel injection system. Fuel 2013; 103: 850–861.
8. E. Mancaruso, L. Sequino, B.M. Vaglieco. Analysis of the pilot injection running Common rail strategies in a research diesel engine by means of infrared diagnostics and 1D model. Fuel 2016; 178: 188–201.

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